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Newfoundland and Labrador Region
Canadian Science Advisory Secretariat
Science Advisory Report 2014/001

STOCK ASSESSMENT OF NAFO SUBDIVISION 3PS COD

Image: Gadus morhua

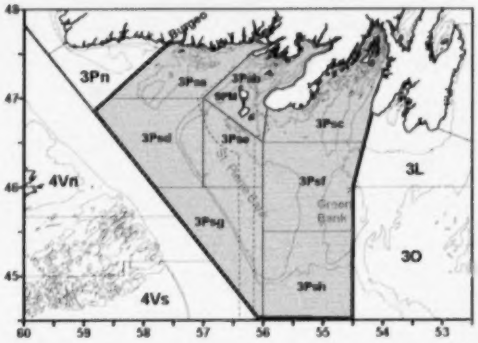

Figure 1: 3Ps management area (shaded) unit areas (solid lines) and economic zone around the French islands of St. Pierre and Miquelon (SPM) (dashed line)

Context:

In the Northwest Atlantic, cod are distributed from Greenland to Cape Hatteras and are managed as 12 stocks. The 3Ps stock off southern Newfoundland extends from Cape St. Mary's to just west of Burgeo Bank, and over St. Pierre Bank and most of Green Bank (Figure 1).

The distribution of 3Ps cod does not conform well to management boundaries and the stock is considered a complex mixture of inshore and offshore sub-components. These may include fish that move seasonally between adjacent areas as well as fish that migrate seasonally between inshore and offshore. The extent to which the different components contribute to the fisheries is not fully understood.

Cod from this stock generally grow faster than those from areas further northward. Female cod from this stock are generally maturing at younger ages in recent years. For example, about 50% of the females are mature by age 5 (~47 cm) in recent cohorts, compared to only about 10% at age 5 (~55 cm) among cohorts present in the 1970s-early 1980s.

Catches from this stock have supported an inshore fixed gear fishery for centuries and are of vital importance to the area. Fish are caught offshore by mobile and fixed gear, and inshore by fixed gear only. Spanish and other non-Canadian fleets heavily exploited the stock in the 1960s and early 1970s. French catches increased in the offshore throughout the 1980s. A moratorium on fishing initiated in August 1993 ended in 1997 with a quota set at 10,000 t. Beginning in 2000, the management year was changed to begin on 1 April. The Total Allowable Catch (TAC) for the 2013/14 management year was set at 11,500 t. Under the terms of a 1994 Canada-France agreement, Canada holds 84.4% of the TAC, while the remainder (15.6%) is held by France (St. Pierre et Miquelon).

The present assessment is the result of a request for science advice from the Fisheries Management Branch (NL Region). The main objectives were to evaluate the status of the stock and to provide scientific advice concerning conservation outcomes related to various fishery management options.

Participants included Fisheries and Oceans Canada (DFO) scientists, a scientist from IFREMER (France), fisheries managers, academia, government officials from the province of Newfoundland and Labrador, and fishing industry representatives from both Canada and France.

This Science Advisory Report is from the October 15-18, 2013 3Ps Cod and Witch Flounder Stock Assessment. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Canada

SUMMARY

- Information available to evaluate stock status consisted of total commercial landings (1959-2012), log-book data (1997-2012), Canadian research vessel (RV) trawl surveys (1972-2013), sentinel surveys (1995-2013), Canadian observer data (1997-2012), results of recent tagging experiments (2009-12) and a telephone survey of Canadian fish harvesters pertaining to the 2012/13 fishery. Consistent with recent assessments, a survey based cohort model (SURBA) was used to infer overall stock trends.
- Reported landings by both Canada and France have been below the TAC since the 2009/10 season, and the proportion of the TAC taken has been decreasing. During the 2012/13 season, less than half (42%) of the 11,500 t TAC was landed.
- Sentinel gillnet catch rates have been very low since 1999, and in 2012 the gillnet index was near the lowest in the time-series. Sentinel linetrawl catch rates from the past four years have also been below average.
- Gillnet catch rates from logbooks of vessels <35' have been stable since 1999, though the 2012 estimate is the lowest in the time-series. Linetrawl catch rates decreased over 2006-10, and have subsequently been relatively stable near the time-series average.
- Although at-sea observer coverage is relatively low for most years and areas (overall, 1.5% for fixed gear; 14% for mobile gears), catch rates from gillnets, line-trawls and otter trawls generally support that recent values are among the lowest in the time-series (1997-2012).
- Average annual exploitation rates based on various size groups of cod tagged and released in Placentia Bay have been variable over 2009-12. In 2011, estimates ranged from 7-14% but increased to 11-21% in 2012, even though the full TAC was not taken in either year.
- Total mortality rates reflect mortality due to all causes, including fishing. Estimated total mortality from a cohort model has been decreasing since 2006, with an average 2010-12 value of 0.44 (36% annual mortality). Current mortality rates are near the time-series average when less than half of the 2012/13 TAC was taken.
- Recent recruitment (2004-09 cohorts) has improved. In particular, the 2006 cohort is estimated to be well above the time-series (1983-2012) average, and preliminary indications are that the 2011 cohort is the strongest in the time-series.
- The basis for a limit reference point (LRP) for this stock is $B_{Recovery}$, defined as the lowest observed spawning stock biomass (SSB) from which there has been a sustained recovery. The 1994 value of SSB has been identified as the limit reference level for this stock.
- Over 2009-13, SSB has increased considerably. The 2013 estimate is approximately twice the level of the LRP, and is near the (1983-2013) time-series maximum. The probability of being below the LRP in 2013 is very low (<0.01).
- Three-year projections were conducted assuming future mortality rates will be within ±20% of current values (2010-12 average). Projection scenarios indicate that the 2014 SSB will remain stable or increase slightly from the 2013 estimate. However, by 2016, results indicate SSB will increase to about 3 to 4 times the LRP. The particularly large increase in SSB projected from 2015 to 2016 is highly uncertain, being heavily influenced by the very large preliminary estimate for the 2011 year-class.

INTRODUCTION

History of the fishery

The stock was heavily exploited in the 1960s and early 1970s by non-Canadian fleets, mainly from Spain, with catches peaking at 87,000 t in 1961 (Fig. 2).

After the extension of jurisdiction in 1977, landings increased to peak at almost 59,000 t in 1987 due to increased landings by France. Landings then decreased sharply to a level of about 40,000 t during 1998-91 before decreasing further to 36,000 t in 1992.

A moratorium was imposed in August 1993 after only 15,000 t had been landed. Although offshore landings fluctuated, the inshore fixed gear fishery reported landings around 20,000 t each year until the moratorium.

The fishery reopened in May 1997 with a TAC of 10,000 t, and increased to 30,000 t by 1999. In 2000 the management year was changed to begin on 1 April. Total Allowable Catches and landings over the past decade are shown in Table 1 and are described in detail below. The TAC for the most recent four management years was set at 11,500 t.

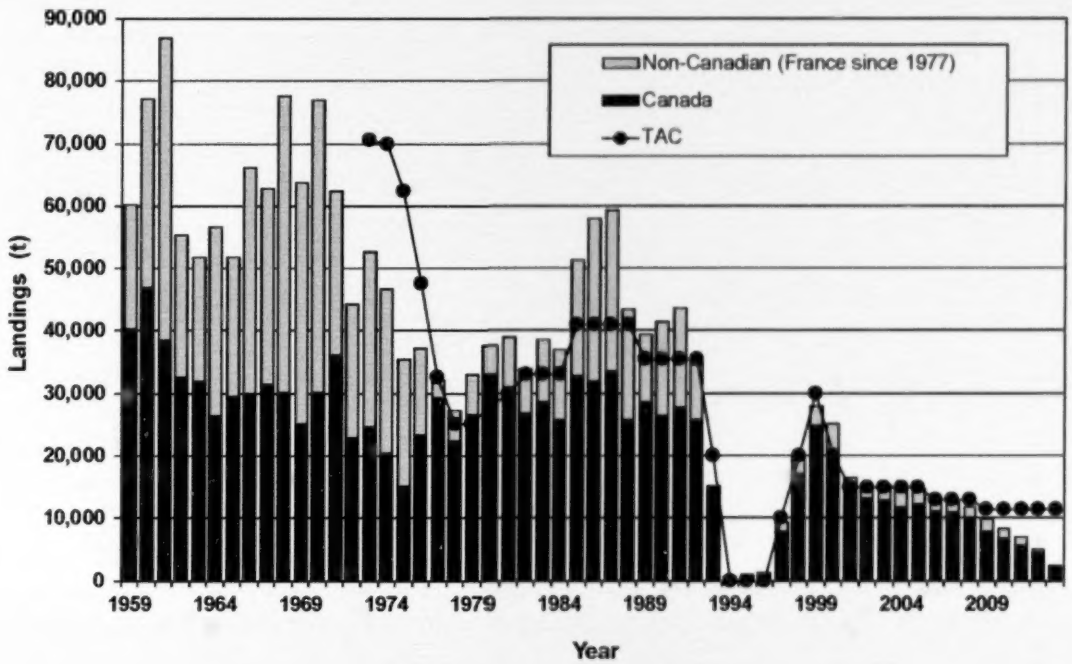

Figure 2. Reported annual landings and TACs (t) from 1959-2013. Values are based on calendar year from 1959-2000 and on management year (1 April-31 March) since then. Landings for 2013 (2013/14 season) are incomplete.

Landings

Table 1: Landings by management year (thousand metric tons).

Management Year	04-05	05-06	06-07	07-08	08-09	09-10	10-11	11-12[1]	12-13[1]	13-14[1,2]
TAC[3]	15.0	15.0	13.0	13.0	13.0	11.5	11.5	11.5	11.5	11.5
Canada	12.1	11.7	11.3	10.8[4]	10.6[4]	7.5[4]	6.6[4]	4.9[4]	4.0[4]	1.5[4]
France	2.4	2.2	1.9	2.0	2.0	1.5	1.3	1.1	0.8	<0.1
Totals	14.5	13.9	13.2	12.8	12.6	9.0	7.8	6.0	4.8	1.5

[1] Provisional.

[2] Approximate landings to 03 October 2013.

[3] TAC is shared between Canada (84.4%) and France (St. Pierre and Miquelon; 15.6%).

[4] Does not include Canadian recreational fisheries.

Reported landings by both Canada and France have been substantially below the TAC since the 2009/10 season, and the proportion of the TAC taken has been decreasing. During the 2012/13 season, less than half (42%) of the 11,500 t TAC was landed. Prior to 2009/10, the TAC has typically been almost fully subscribed with the exception of the initial four years of TAC regulation. Industry participants have indicated multiple reasons contributing to the recent reduction in landings, mainly relating to economic factors, but reduced availability has been a concern for some areas at certain times of year. Of the 4,798 t landed during the 2012/13 season, 4,038 t was taken by Canada (including 14 t from sentinel surveys), and 760 t was landed by France.

Provisional data (as of 3 October 2013) indicate landings during the ongoing 2013/14 management year were 1,512 t, 8 t of which was landed by France. Although incomplete, these landings to date are relatively low, and suggest that much of the 2013/14 TAC of 11,500 t will not be caught.

The level of total removals is uncertain. It is likely that historical landings have been biased both upwards (e.g., due to misreporting of catch by area and/or species) and downwards (e.g., due to discarding). In addition, commercial catch accounting procedures pre- and post-moratorium are radically different, with current measures likely to provide improved estimates of removals. In assessing stock status, it would be useful to better understand the accuracy of total removals, especially in the post-moratorium period. Estimates of recreational fishery landings have not been available since 2006.

During the 2012/13 season, approximately two-thirds of the total landings were taken by fixed gears (dominated by gillnet) with the remainder taken by the otter trawl fleet.

Species Biology

Stock structure and **migration patterns** of 3Ps cod are complex. Cod in 3Ps mix with adjacent stocks at the margins of the stock boundary. Some offshore components of the stock migrate seasonally to inshore areas, and there are inshore components that are shoreward of the spring DFO RV trawl survey area. These features add uncertainty to the assessment of stock status. However, since the moratorium, new information has been obtained from various sources,

including tagging, acoustic telemetry, and the sentinel fishery. This information has provided a basis for several new measures to be put in place to reduce the potential impact of these factors (i.e., stock structure and migration patterns) on the assessment. Survey timing has been delayed until April (beginning in 1993) and winter area closures have been imposed to reduce the possibility that migrant non-3Ps cod are included in surveys and commercial catches. The area surveyed during the spring DFO RV trawl survey has also been extended shoreward and by 1997 the total area covered increased by 12%. The spring DFO RV trawl survey covers most of the stock so survey trends broadly reflect stock trends.

Maturation in female cod was estimated by cohort. The proportion of female cod maturing at ages 4-6 has increased for all cohorts subsequent to the 1985 cohort. The reasons for the change toward earlier age at maturity are not fully understood but may have a genetic component that is partly a response to high levels of mortality including fishing. Males generally mature about one year younger than females but show a similar trend over time.

Spawning is spatially widespread in 3Ps, occurring close to shore as well as on Burgeo Bank, St. Pierre Bank, and in the Halibut Channel. Timing of spawning is variable and extremely protracted, with spawning fish present from March until August in Placentia Bay. A recent review of spawning time found no indication of any shift in the timing of spawning over the 1997-2009 period.

Growth, calculated from length at age in research trawl survey samples, has varied over time. For cod older than age 3 there was a general decline in length-at-age from the early 1980s to the mid-1990s. For most ages there was an increase in length-at-age from the mid-1990s through the mid-2000s. Subsequent trends have been more variable, but data from 2011-13 surveys indicate that mean length-at-age for ages 3-8 has been below the time-series average. Length-at-age for fish sampled in the sentinel survey has declined since 1998 in fish ages 4 and older.

Comparison of post-1992 **condition** with that observed during 1985-92 is difficult because survey timing has changed. Condition varies seasonally and tends to decline during winter and early spring. Body and liver condition in 2013 increased to above average following five years of mainly below average values. Seasonally, fish and liver condition observed in sampling from the sentinel surveys were highest in the fall and declined over the winter and early spring. Annually, trends in condition have varied, and sentinel sampling in 2011 indicates condition was below the time-series average.

ASSESSMENT

Resource Status

Sources of information

Sources of information included total **commercial landings** through September 2013, logbook data (1997-2012), **abundance indices** from Canadian RV trawl surveys (1972-2013), Canadian observer data (1997-2012) and sentinel surveys (1995-2013). Results of a telephone survey of inshore Canadian fish harvesters and exploitation (harvest) rates estimated from tagging experiments in Placentia Bay were also available.

Research vessel surveys

Canadian DFO RV bottom **trawl surveys** have been conducted since 1972, however, surveys from 1972-82 had poor coverage. The surveyed area was increased by 12% during 1997 when

additional areas closer to shore was added to the survey design. The DFO RV survey was not completed in 2006 due to unforeseen operational difficulties.

Survey indices are presented for the expanded DFO survey area (inshore and offshore; denoted "Combined" in figures) as well as for the offshore strata ("Offshore" in figures). The DFO RV survey covers most of the stock distribution, and survey trends broadly reflect stock trends. Any near-shore aggregations in April would not be measured by the DFO RV survey. The majority of the area shoreward of the DFO RV survey lies within inner and western Placentia Bay. There is no recent evidence that a large fraction of the stock is shoreward of the DFO RV survey in April.

The **biomass index** from the offshore strata is variable but declined from the mid-1980s to the early 1990s (Fig. 3). Values for most of the post-moratorium period up to 2004 were higher than those of the early 1990s, but not as high as those of the 1980s. The survey index shows a general declining trend over 2001 to 2008, a pattern which has reversed in recent years. In 2013, biomass has increased to above average, though the estimate is imprecise. Survey catches were highest on Burgeo Bank, the southern edge of the Hermitage Channel and the Halibut Channel. Survey biomass from the combined index ("All Strata <300 fms") shows similar trends to the offshore-only index.

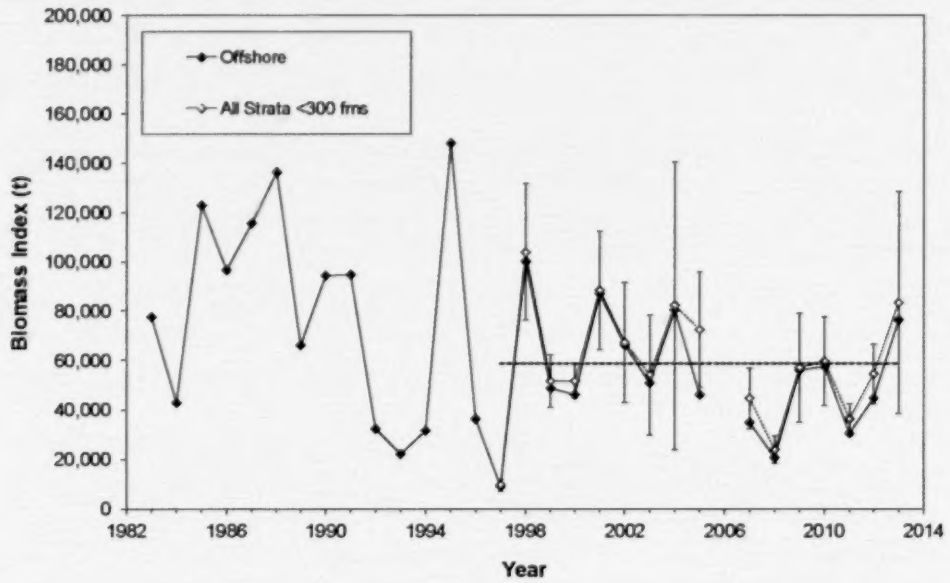

Figure 3. Research vessel survey biomass indices (t) (error bars are 95% confidence intervals for combined survey index–dashed line is the time series average of the combined survey index).

The offshore DFO RV abundance index is variable, but values during the 1990s were generally lower than those from the 1980s (Fig. 4). The index generally declined from 1999 to 2008. The index increased considerably in the last few years, due to increased abundance of young cod (less than age 5), and is currently well above average, near the time-series high.

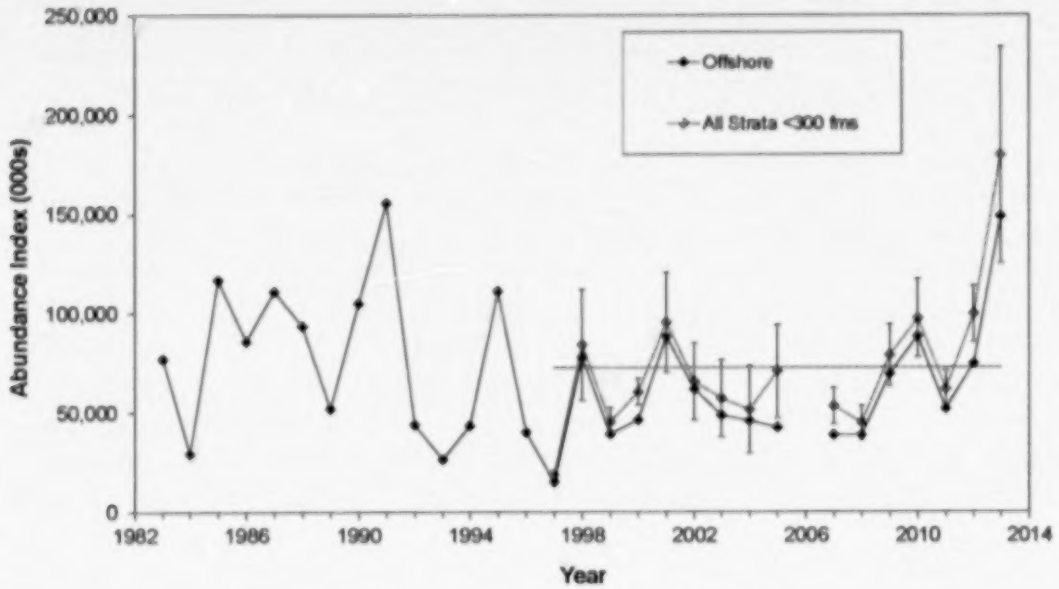

Figure 4. Research vessel survey abundance indices (error bars are 95% confidence intervals for combined survey – dashed line is average of combined survey index).

Age Composition

Catches during the 2013 RV survey consisted mainly of cod aged 2-4 (72% of abundance index). Survey abundance of the 2006 year-class, now seven years old, was above the average of previous age 7 observations. During 2013, both the age 1 and age 2 values were very large, with each well above the 1983-2013 average, particularly the 2011 year-class (age 2 in 2013). Further, catches of age 2 fish were widely distributed throughout the survey area. The degree to which the abundant 2011 and 2012 year-classes will contribute to future fisheries is as yet uncertain.

Cohort Analysis Reference Points

The LRP for this stock is $B_{Recovery}$, based on the lowest observed SSB from which there has been a sustained recovery. The 1994 value of SSB has been identified as the LRP. Removal reference points have not been identified for this stock.

Spawning Biomass:

Cohort analyses of the RV data indicated that SSB declined by more than 60% over 2004-09 (Fig. 5). Median SSB was estimated to be below the LRP in 2008 and 2009. SSB has increased considerably over 2009-2013. The 2013 estimate is approximately twice the level of the LRP, and is near the (1983-2013) time series maximum. The probability of being below the LRP in 2013 is very low (<0.01). As a result of improved recruitment and recent increases in the

proportion mature-at-age, 71% of the 2013 SSB is comprised of young (age 5-7) fish.

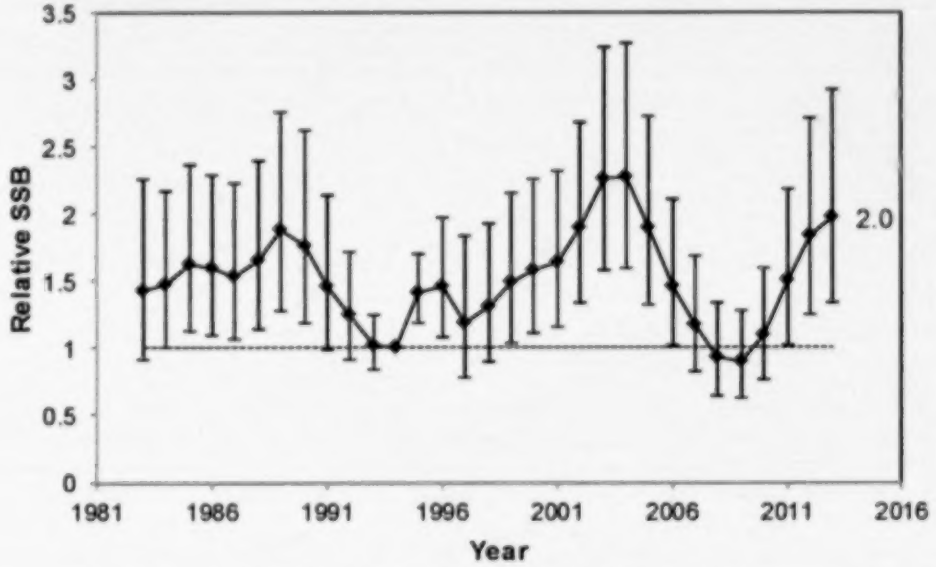

Figure 5. Cohort analysis estimates of SSB, relative to the 1994 value (median estimate with 95% confidence interval). A horizontal dashed line at one (reference level) represents the SSB Limit Reference Point. Text label indicates the current SSB relative to the LRP.

Mortality Rates

Total mortality rates reflect mortality due to all causes, including fishing. Estimated total mortality from a cohort model (Fig. 6) declined from 2006-2012, with an average 2010-12 value of 0.44 (36% annual mortality). This value is weighted by population number at each of ages 5-10. Further, average mortality (unweighted) values indicate broadly similar trends, but have larger magnitude as the oldest age groups (which have highest mortality) are more influential. Though mortality rates have decreased in recent years, current estimates are near the time-series average even though less than half of the 2012/13 TAC was taken. It remains unclear whether or not these mortality rates are sustainable over the longer term.

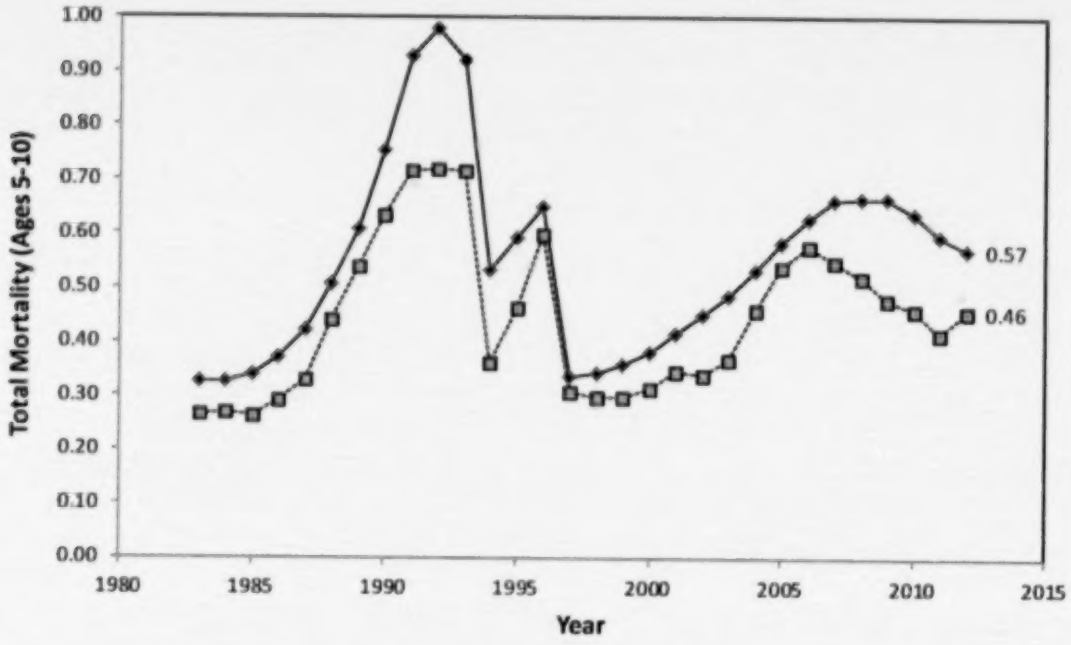

Figure 6. Cohort analysis estimates of total mortality over ages 5-10. Solid line: average annual mortality; dashed line: average annual mortality weighted by population number at ages 5-10. Text labels indicate the estimated total mortality for 2012.

This analysis assumes that age 4 and older fish are equally selected (flat-topped) by the RV survey. Alternate assumptions for the relative catchability (domed) of cod ages 4+ were explored in a previous assessment and gave similar trends (see DFO, 2009). Flat-topped selectivity is commonly assumed unless there is evidence otherwise.

Recruitment

Estimates of recruitment (Fig. 7) indicate an increase in recent years, with several successive year-classes (2004-2009) estimated to be much improved compared to the preceding five estimates. In particular, the 2006 cohort is estimated to be well above the time-series (1983-2012) average. Preliminary indications are that the 2011 cohort is the strongest in the time-series, yet the degree to which this year-class (as well as the preliminary estimate for the 2012 year-class) is expected to contribute to the fishery may be revised as additional data are collected.

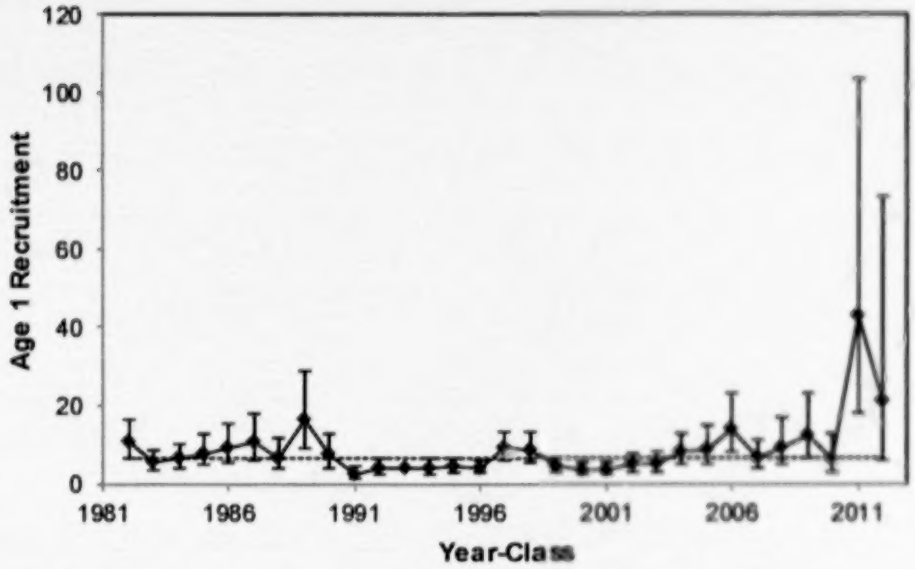

Figure 7. Estimated relative year-class strength from cohort model (median estimate with 95% confidence intervals). The dashed horizontal line is the time-series median.

Projection

Three-year projections were conducted assuming future mortality rates will be within ±20% of current values (2010-12 average). Projection scenarios indicate that the 2014 SSB will remain stable or increase slightly from the 2013 estimate. However results indicate SSB will increase to about 3 to 4 times the LRP level by 2016. The particularly large increase in SSB projected from 2015 to 2016 is highly uncertain, being heavily influenced by the very large preliminary estimate for the 2011 year-class. Almost half of the projected SSB 2016 is comprised of this year-class, even though it will be only five years old. In each of the scenarios, the probability of being below the LRP over 2014-2016 is very low (<0.01).

Sentinel survey

Fixed gear **sentinel surveys** have been conducted at sites along the south coast of Newfoundland from St. Bride's to Burgeo from 1995 through 2013. Gillnet results come mostly from sites in Placentia Bay whereas line-trawl results come mostly from sites west of the Burin Peninsula. The sentinel survey for 2013 is still ongoing; hence, the data for 2013 are incomplete and were not included in the modeling reported below.

The sentinel survey data were standardized to remove site and seasonal effects to produce annual indices of the total and age-specific catch rates (Fig. 8).

The standardized total annual **catch rate** for gillnets was highest from 1995-97, but progressively lower in 1998 and 1999, and remained quite low from 2000 to 2012 (Fig. 8, upper panel). The 2011 and 2012 results are the lowest of the time-series. The line-trawl catch rates were high in 1995 with a steady decline to 1999, but were subsequently fairly constant through 2009 (Fig. 8, lower panel). Most recent values are among the lowest in the time-series. Although considerable declines have been estimated by both gear types, the magnitude of this decline is inconsistent across gear types. Current gillnet estimates are 77% below the time-series average, whereas current line-trawl values are only 30% lower than average.

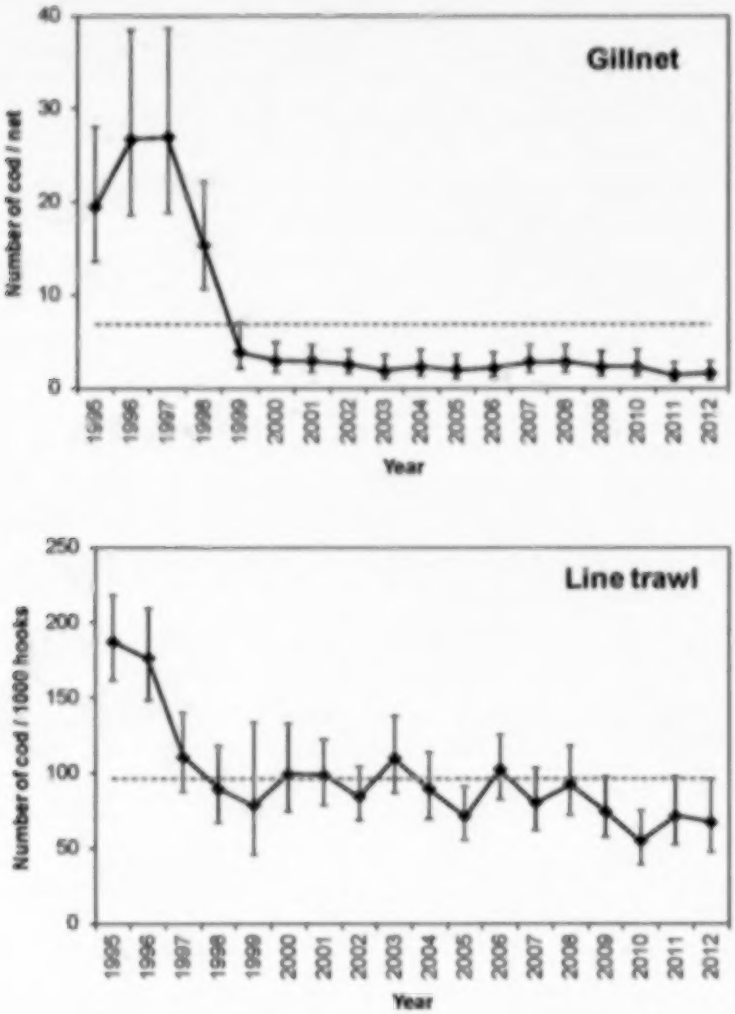

Figure 8. Standardized sentinel catch rates for gillnets (upper panel) and line-trawls (lower panel). Error bars are 95% confidence intervals; dashed lines represent the time-series average.

Age composition

The standardized age-specific catch rates for gillnets and line-trawls show similar trends with the relatively strong 1989 and 1990 year-classes being replaced by subsequent weaker year-classes resulting in an overall decline in catch rates. Although the magnitude of the sentinel catch rates has been generally constant for more than a decade, the 1997 and 1998 year-classes were consistently evident in both age disaggregated sentinel indices. In addition, the 2004 year-class appears to be well-represented only within line-trawl results. The relative strength of more recent year-classes in the sentinel results is less clear, but generally indicates that they are relatively weak. Comparison of sentinel catch rates and the RV index at times show inconsistent age compositions; these differences are not fully understood. As an example, the 2006 year-class ranks above average in the RV survey, but does not appear particularly

strong in either sentinel index even though fish in this year-class are now available to these gears.

Logbooks

There is considerable uncertainty in the interpretation of fishery catch rate data. These data may be more reflective of changes in the nature of the fishery than changes in population size.

<35' Vessels

Standardized annual catch rates from science logbooks (<35' sector) for Canadian vessels fishing gillnets show a declining trend over 1998-2000, but have subsequently been fairly constant (Fig. 9, upper panel). Catch rates for 2012 are the lowest in the time-series. Line-trawl catch rates show a much different pattern with a greater degree of variation (Fig. 9, lower panel). After peaking in 2006, line-trawl catch rates generally declined and in 2012 were near the time-series average. The commercial catch rate index is based on weight of fish caught whereas the sentinel index is based on numbers. As with the sentinel results, there is contrast between the two gear-types in current catch rates relative to the time-series average. For gillnets, current CPUE is 25% below average, whereas for line-trawl, current CPUE is 10% below average.

The percentage of the catch from the <35' sector that is accounted for in the standardized logbook indices has declined over time and now represents less than 35% of the catch as compared to approximately 70% at the start of the time series in 1997. This likely affects the quality, and comparability, of this index over time, such that it is unclear if the CPUE trends reflect the fishery as a whole.

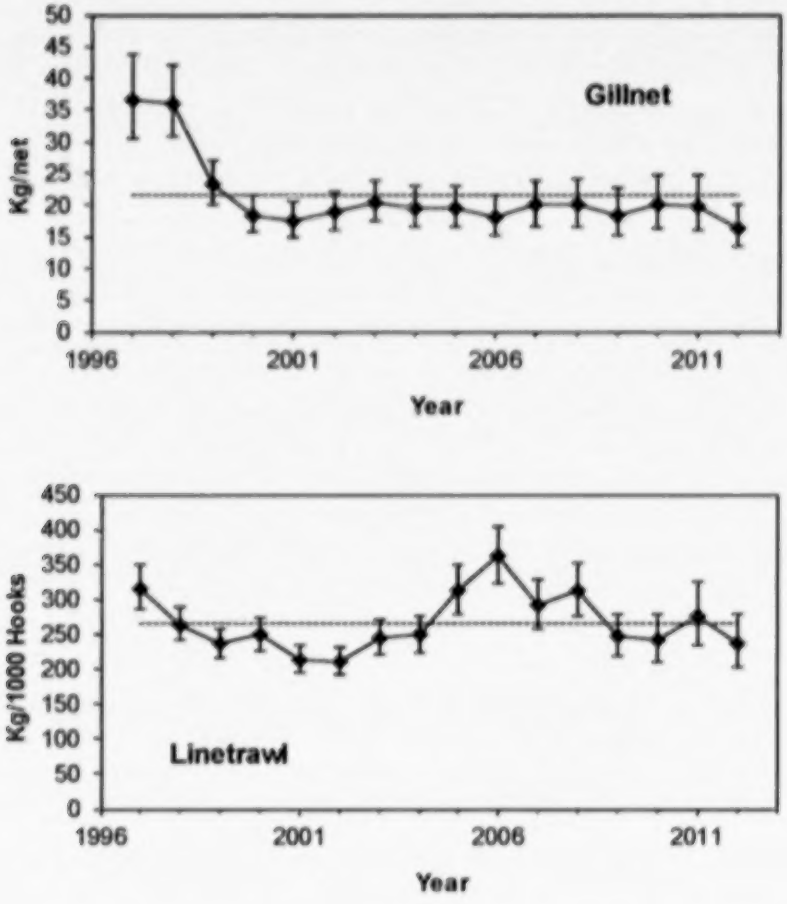

Figure 9. Standardized catch rates for gillnets and line-trawls from science logbooks for vessels <35'. Error bars are 95% confidence intervals; dashed line is the time-series average.

Tagging

During 2008-12, tagging was conducted in Placentia Bay in spring (May-June). Although exploitation rates based on tagging of cod in Placentia Bay may not be applicable to other areas, or to the stock as a whole, this area accounts for a significant portion (~ 25-35%) of the overall annual landings from the stock.

Average annual exploitation rates based on various size groups of cod tagged and released in Placentia Bay have been variable over 2008-12. In 2011, estimates ranged from 7-14% but increased to 11-21% in 2012, even though the full TAC was not taken in either year. Estimates of exploitation rates from tagging can be influenced by the sizes of cod tagged due to selectivity of commercial fishing gear. Larger cod (>65 cm) tend to be more readily selected by gill nets compared with smaller ones.

The number of cod tagged in Placentia Bay has been reduced in recent years. Furthermore, no other tagging has been conducted in 3Ps over 2008-12. Therefore, exploitation rates based on

tagging are no longer available for the offshore (Halibut Channel and Burgeo Bank), Fortune Bay, or Hermitage Bay.

Observer Data

Information collected at sea by observers on Canadian vessels fishing for cod (1997-2012) were reviewed for the potential to create a standardized catch rate index from these data in future assessments. Data exploration indicated substantial variations in observer coverage over time and among unit areas, as well as by fleet sector. On average, (over the full time-series) approximately 14% of the otter trawl landings were observed compared to 1.5% of gillnet and line-trawl landings. Although the proportion of the landings observed is low for most years and areas, data from gillnets, line-trawls and otter trawls generally support that recent catch rates are among the lowest in the times series (1997 to 2012). Further explorations will be pursued, but the utility of this work may be limited by the fact that observer deployments are sometimes not random but targeted to gather information related to management issues (e.g. whether or not areas should be closed due to prevalence of under-sized fish).

Sources of Uncertainty

The level of total removals is uncertain. It is likely that historical landings have been biased both upwards (e.g., due to misreporting of catch by area and/or species) and downwards (e.g., due to discarding). In addition, commercial catch-accounting procedures pre- and post-moratorium are radically different, with current measures likely to provide improved estimates of removals. In assessing stock status, it would be useful to quantify the accuracy of total removals, especially in the post-moratorium. Estimates of recreational fishery landings have not been available since 2006.

There is uncertainty regarding the origins of fish found in 3Ps at various times of the year. Tagging and telemetry experiments show that there is mixing with adjacent stocks (southern 3L and 3Pn4RS) and this may vary over time. However, results indicate that exploitation of fish tagged within Placentia Bay has been predominantly within that area, even after several years at liberty.

Comparison of sentinel catch rates and the RV index at times show inconsistent age-compositions. The differences in cohort strength between stock components could be due to changing stock distribution within the year, gear selectivity, or the spatial coverage of each index. As an example, the sentinel gillnet data consistently measured the 1992 cohort as being an above average fraction of the annual catch. This cohort was also important to the commercial gillnet catch, but was not notable in the RV index. A similar phenomenon exists for the 2004 cohort (detected by sentinel line-trawl but not sentinel gillnet or RV index).

The geographical coverage of tagging since 2007 is very limited; during 2008-12 cod were only tagged in Placentia Bay. The lack of recent tagging in other areas adds uncertainty to our understanding of natural mortality rates, exploitation rates, stock structure, as well as movement patterns and how these influence survey and commercial catch rates in the recent period.

The relative efficiency of the survey trawl at capturing different age groups is uncertain. Differing patterns of catchability were explored in recent assessments and yielded a similar outcome in terms of current status relative to the LRP. If the catchabilities differ from the assumed values, stock dynamics may differ from the results presented above.

Survey indices are at times influenced by "year-effects", an atypical survey result that can be caused by a number of factors (e.g., environmental conditions, movement, degree of aggregation, etc.) which may be unrelated to absolute stock size. In the 2013 RV survey, the

estimated abundance of multiple cohorts increased compared to observations of these same cohorts at one age younger in 2012. For some cohorts, this change is influenced by a single survey catch that was relatively large. The nature of the increase between 2012 and 2013 is unusual and indicates that one (or possibly both) of these surveys may be influenced by a year-effect. A similar situation was observed between 2008 and 2009, and year-effects are also evident in the 1995 and 1997 survey results.

The percentage of the catch from the <35' sector that is recorded within the logbook database has declined over time and now represents only about 35% of the catch as compared to approximately 70% at the start of the time series in 1997. This likely affects the quality and comparability of the standardized catch rate index derived from this data over the time series.

Age at 50% maturity has been declining in recent years. The proportion of female cod maturing at younger ages has increased for all cohorts subsequent to the 1986 cohort, resulting in an increased proportion of young fish contributing to the SSB. It is uncertain whether or not these small, young fish are effective spawners.

As a result of improved recruitment and recent increases in the proportion mature-at-age, 71% of the 2013 SSB is comprised of young (age 5-7) fish, which is relatively high.

CONCLUSIONS AND ADVICE

- Information available to evaluate stock status consisted of total commercial landings (1959 to 2012), log-book data (1997-2012), Canadian research vessel (RV) trawl surveys (1972-2013), sentinel surveys (1995-2013), Canadian observer data (1997-2012), results of recent tagging experiments (2009 to 2012) and a telephone survey of Canadian fish harvesters pertaining to the 2012/13 fishery. Consistent with recent assessments, a survey based cohort model (SURBA) was used to infer overall stock trends.
- Reported landings by both Canada and France have been below the TAC since the 2009/10 season, and the proportion of the TAC taken has been decreasing. During the 2012/13 season, less than half (42%) of the 11,500 t TAC was landed.
- Sentinel gillnet catch rates have been very low since 1999, and in 2012 the gillnet index was near the lowest in the time-series. Sentinel line-trawl catch rates from the past four years have also been below average.
- Gillnet catch rates from logbooks of vessels <35' have been generally stable since 1999, though the 2012 estimate is the lowest in the time series. Line-trawl catch rates decreased over 2006-10, and have subsequently been relatively stable near the time-series average.
- Although at-sea observer coverage is relatively low for most years and areas (overall, 1.5% for fixed gear; 14% for mobile gears), catch rates from gillnets, line-trawls and otter trawls generally support that recent values are among the lowest in the time series (1997 to 2012).
- Average annual exploitation rates based on various size groups of cod tagged and released in Placentia Bay have been variable over 2009-2012. In 2011, estimates ranged from 7-14% but increased to 11-21% in 2012, even though the full TAC was not taken in either year.
- Total mortality rates reflect mortality due to all causes, including fishing. Estimated total mortality from a cohort model has been decreasing since 2006, with an average 2010-2012 value of 0.44 (36% annual mortality). Current mortality rates are near the time-series average even though less than half of the 2012/13 TAC was taken.
- Recent recruitment (2004-2009 cohorts) has improved. In particular, the 2006 cohort is estimated to be well above the time-series (1983-2012) average, and preliminary indications are that the 2011 cohort is the strongest in the time series.

- The basis for a limit reference point (LRP) for this stock is $B_{Recovery}$, defined as the lowest observed SSB from which there has been a sustained recovery. The 1994 value of SSB has been identified as the limit reference level for this stock.
- Over 2009-2013, SSB has increased considerably. The 2013 estimate is approximately twice the level of the LRP, and is near the (1983-2013) time-series maximum. The probability of being below the LRP in 2013 is very low (<0.01).
- Three-year projections were conducted assuming future mortality rates will be within ±20% of current values (2010-12 average). Projection scenarios indicate that the 2014 SSB will remain stable or increase slightly from the 2013 estimate. However, results indicate SSB will increase to about 3 to 4 times the LRP by 2016. The particularly large increase in SSB projected from 2015 to 2016 is highly uncertain, being heavily influenced by the very large preliminary estimate for the 2011 year-class.
- Removal reference points or productivity based reference points have not been identified for this stock. It remains unclear whether or not current mortality rates are sustainable over the longer term.

OTHER CONSIDERATIONS

Management Considerations

The level of total removals is uncertain but less so in the post-moratorium period. In assessing stock status, it would be useful to better understand the accuracy of total removals. Accurate estimates of recreational fishery landings are also required.

Estimation of MSY-based reference points (FMSY and BMSY) will require an assessment framework review including further peer review of the modeling approach used to quantify these reference points.

Management should recognize that cod which overwinter in 3Ps are also exploited in adjacent stock areas (Division 3L and Subdivision 3Pn). Hence management actions in these stock areas should consider potential impacts on 3Ps cod. Consequences of area/time closures should be carefully considered as these may result in higher exploitation rates on the components of the stock that remain open to fishing. The fishery should be managed such that catches are not concentrated in ways that result in high exploitation rates on any stock components.

Management should be aware of within-year variations in the individual weight of cod. Greatest individual yield can be gained when fish are in peak condition, typically in late fall/early winter, while minimizing the total number of individuals removed from the stock.

When average fish size (age) in commercial catches is reduced through either depletion of older cohorts or recruitment of younger cohorts, the numbers of fish removed per ton of landed catch is increased.

Temperature and Physical Oceanography

Oceanographic information collected during the spring DFO RV surveys indicated that near-bottom temperatures throughout NAFO subdivision 3Ps have been warming during the past decade reaching two standard deviations above normal in 2011 and 2012 before decreasing to one standard deviation above normal in 2013. Survey catches of cod are generally lower in years where relatively large incursions of cold/fresh water from the eastern NL shelf dominate, indicating an apparent effect on cod distributions and their availability to the RV surveys. Furthermore, significant positive correlations were found between survey abundance and both

bottom temperature and the area of the bottom habitat covered by water with temperatures greater than 2°C. The areal extent of bottom water with temperatures >2°C has remained relatively constant at about 50% of the total 3Ps area, although actual temperature measurements show considerable inter-annual variability. The current conditions are comparable to those of the late 1970s and early 1980s when the stock was more productive and indeed some of the recent improvements in recruitment have coincided with the warming temperature trend.

Ecosystem Considerations

Considering the broader ecosystem-wide perspective, the fish community in 3Ps declined during the mid-1980s, and early-1990s; this decline was also accompanied by a decrease in the average fish size. Since the mid-1990s, the overall biomass and abundance of the fish community has increased. The overall biomass increase has been moderate, but the increase in abundance has been clear, being led by planktivorous (plankton-eating) fishes.

Atlantic cod is an important and dominant species among piscivorous (fish-eating) fishes in 3Ps. In the late 2000s and early 2010s, although cod remains as the dominant component in this fish functional group, its dominance level has lessened, and other species (mostly silver hake (*Merluccius bilinearis*), but also pollock (*Pollachius virens*) in some years) have increased their share of the overall piscivorous fish biomass. These are "warmer-water" species, and their increases may be linked to the warming trend in this ecosystem.

The observed warming of this system, together with recent increases of "warmer-water" species like sandlance (*Ammodytes americanus*), silver hake, and pollock suggests that this ecosystem could be undergoing structural changes. Until the extent and magnitude of these changes can be properly evaluated, system-wide management with higher than normal risk aversion would be advisable.

Stakeholder Perspectives

Fishing effort and landings have continued to decline in the past number of years due to a number of contributing factors. Fish harvesters are concerned about the low abundance of capelin and the potential impact it is having on cod migration, condition/health and abundance. There is growing concern that the expanding population of grey seals has negatively impacted cod abundance. The economic viability of the harvest is impacted by the market price; increased bait and fuel costs; and the absence of willing buyers throughout the fishing season.

Canadian fixed-gear fish harvesters' perspectives were compiled based on the results of the 2012 fishery. A telephone survey was conducted by the FFAW during February of 2013. Most fish harvesters felt that the 2012 abundance was about the same when compared to 2011. Fish harvesters were asked to rate their 2012 catch rates in comparison to his/her historical perspective; with 1 being the worst and 10 being the best, most responses ranged from 5 to 8. The size range of cod observed in 2012 was mostly an even mixture of all sizes and size range observed from 2011 to 2012 fishing season was the same size. An overwhelming majority of fish harvesters stated the condition or health of cod was good. Fish harvesters felt that the baitfish, capelin, herring, squid and mackerel were at a low level and declining.

3Ps-based harvesters are encouraged by the positive signs of recruitment, but still have some concerns about overall health of the 3Ps stock.

In Saint-Pierre et Miquelon, the smaller (<65 feet) fleet holds 30% of the French TAC for 3Ps cod (for 2013/14 season: 539 tons). Since the plant in Miquelon exclusively works with the fish

provided by its own vessel, and in the absence of a plant in Saint-Pierre, this cod is currently sold to Newfoundland plants.

As of 7 October 2013, the <65 feet French fleet has caught a minimal amount of its quota. Newfoundland plants are not accepting cod yet, due to very low prices. As such, the Saint-Pierre et Miquelon fishermen have not directed their efforts towards cod for now. If Newfoundland plants start accepting cod, the fishing effort may increase before the end of the season. The fishermen are concerned by the lowering of prices.

Most fish encountered by Canadian offshore vessels were small (50 cm to 60 cm). Landings were well below quota levels because of variable market demand for 3Ps cod and global competition from international cod producers. Several wetfish vessels that fished 3Ps cod in recent years and were important harvesters of this stock were sold or decommissioned. The sector remains optimistic about the future of this fishery, its challenges and in the continued rebuilding of this stock.

SOURCES OF INFORMATION

This Science Advisory Report is from the October 15-18, 2013 3Ps Cod and Witch Flounder Stock Assessment. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Cadigan, N.G. 2010. Trends in Northwest Atlantic Fisheries Organization (NAFO) Subdivision 3Ps Cod (*Gadus morhua*) stock size based on a separable total mortality model and the Fisheries and Oceans Canada Research Vessel survey index. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/015.

DFO, 2004. Stock Assessment of Subdivision 3Ps cod. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2004/039.

DFO, 2009. Stock Assessment of Subdivision 3Ps cod. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/063.

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Centre for Science Advice (CSA)
Newfoundland and Labrador Region
Fisheries and Oceans Canada
Northwest Atlantic Fisheries Centre
PO Box 5667
St. John's NL Canada A1C 5X1

Telephone: (709) 772-3332
E-Mail: DFONLCentreforScienceAdvice@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

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